

H₂O and CO₂ spectra toward massive protostars

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The Infrared Space Observatory (ISO) has provided us with a wealth of new data in the infrared from regions of massive star formation. This includes unique information on molecules such as H₂O and CO₂, which are difficult to observe from the ground due to the Earth's atmosphere. H₂O and CO₂ are among the most abundant species in the envelopes of massive protostars and play a key role in the chemistry in these regions. We have studied these two molecules toward ~15 massive young stellar objects, including GL 2136, GL 2591, W 3 IRS5, NGC 7538 IRS9, MonR2 IRS3 and GL 490, using both the Short- and Long Wavelength Spectrometer. Most of these objects show a multitude of gas-phase H₂O absorption lines around 6 μ m in the SWS spectra, originating in the ν_2 ro-vibrational band. The ro-vibrational band at 15 μ m of gas-phase CO₂ has also been detected in many sources. The LWS spectra, however, do not show strong lines of gas-phase H₂O.

H₂O is a particularly powerful molecule to study the interaction of the protostar with its environment. In warm regions and shocks all oxygen not locked up in CO is thought to be driven into H₂O, predicting greatly enhanced gas-phase H₂O abundances. Also, its level populations are influenced by mid- and far-infrared radiation from warm dust, in addition to collisions. The observed H₂O spectra are compared with those derived from detailed models of the physical structure and H₂O chemistry and excitation in the envelopes around massive stars (cf. Doty & Neufeld 1997).

Modeling of the H₂O spectra shows that the H₂O abundances increase with temperature, up to a few times 10⁻⁵ for the hottest sources ($T_{\text{ex}} \sim 500$ K). The presence of strong C₂H₂ absorption toward the same sources (Lahuis & van Dishoeck 1999) suggests that shocks do not play a dominant role. Hot core models by Charnley (1997) indicate abundances of $\sim 10^{-5}$ for $T=300$ K, consistent with our values. However, here it is assumed that the initial solid-state abundance of H₂O is $\sim 10^{-5}$, a factor of 10 lower than observed toward cold sources in which evaporation has not yet started (Keane et al. 1999).

Gas-phase CO₂ is not abundant in our sources. The abundances are nearly constant for $T_{\text{ex}} \gtrsim 100$ K at a value of a few $\times 10^{-7}$, much lower than the solid-state abundances of $\sim 1-3 \cdot 10^{-6}$ (Gerakines et al. 1999).

Gas/solid ratios have been determined, using the solid-state features of H₂O (Keane et al. 1999) and CO₂ (Gerakines et al. 1999) as observed with ISO-SWS toward the same objects. For both species this ratio increases with temperature, but the increase is much stronger for H₂O than for CO₂, suggesting a different type of chemistry. The data are compared with simple chemical models including evaporation based on the physical structure derived by van der Tak et al. (2000).

References

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